Method for regulating the operating frequency and multifunctional integrated optical chip of a fiber-optic gyroscope

The invention relates to a method for regulating the operating frequency of a fiber-optic gyroscope (FOG) with a closed control loop, in which the demodulated output signal of the FOG detector, as actual signal, is applied on the one hand to the input of an FOG main controller and on the other hand, via a gating filter, to a VCO that determines the system clock of the FOG, the output signal of the main controller, as modulation signal, being fed to a digital phase modulator formed in a multifunctional optical chip (MIOC), and, for the purpose of determining and regulating the exact operating frequency of the FOG, a periodic additional modulation signal is superposed on the demodulated detector output signal passing to the gating filter. The invention additionally relates to a multifunctional integrated optical chip (MIOC) for a fiber-optic gyroscope (FOG).

DE 197 53 427 C1 describes a digital phase modulator, in particular for fiber-optic rate-of-rotation sensors with a closed control loop, in which, in order to increase the resolution, a less significant portion of a binary drive signal supplied by an FOG main controller is converted into an analog signal by means of a digital/analog converter having a relatively low resolution, which analog signal is fed to a further electrode that is provided separately on the integrated optical chip containing the digital phase modulator. The resolution can thus be increased from for example 8 to approximately 10 bits. The separate electrode or, if appropriate, a separate electrode pair is assigned directly to the digital phase modulator.

German patent application 101 30 159.6, not published before the priority date, proposes a method for

avoiding bias errors on account of synchronous interference in fiber-optic gyroscopes with a closed control loop, which provides for superposing on the demodulated output signal of the FOG detector a signal, which is periodic at the sampling clock rate of the FOG, in the form of an additional modulation at the digital phase modulator within a multifunctional integrated optical chip. The remainders of this additional modulation that are present in the demodulated detector signal are detected and fed to an auxiliary control loop, which readjusts the operating frequency such that the additional modulation as far as possible tends toward zero.

However, the implementation of this known method, which leads to a considerable increase in the accuracy of FOGs, has led in practice, through the use of a mixed drive signal at the phase modulator of the MIOC, to practical difficulties, in particular to a certain conflict of aims, if it is simultaneously attempted to solve the resolution of the digital phase modulator, without increasing the structural length of the MIOC, differently than is described in the abovementioned German patent specification. This holds true particularly when the phase modulator, for increasing the resolution, is intended to be operated with non-binary drive signals.

The invention is thus based on the object of simplifying the method for regulating the operating frequency of an FOG.

In the case of a method of the generic type mentioned in the introduction, this object is achieved according to the invention by virtue of the fact that a periodic additional signal for determining the frequency or regulating the frequency of the FOG, as analog signal, is fed to separate phase correction electrodes formed in the MIOC.

A multifunctional integrated optical chip (MIOC) for a fiber-optic gyroscope, in which a phase modulator realized by electrodes arranged parallel to a light guiding path is implemented as at least one functional group, is suitable for realizing the method according to the invention by virtue of the fact that, according to the invention, in addition to the phase modulator, an electrode pair arranged parallel to the light guiding path is present for applying a periodic additional modulation signal to a light beam on the light guiding path for the purpose of regulating the operation frequency of the gyroscope.

An optimized structural size of the integrated optical chip can be achieved when the additional electrode pair is arranged between the digital phase modulator and a beam splitter within the chip.

The invention and advantageous details are explained in more detail below in an exemplary embodiment with reference to the drawings, in which:

Figure 1 shows a schematic block diagram of the architecture of an FOG with illustration of the operating frequency regulation according to the invention; and

Figure 2 shows, in a somewhat simplified illustration, the plan view of a multifunctional integrated optical chip (MIOC) with additional electrodes for advantageously realizing the regulating method according to the invention.

The optical architecture of a fiber-optic gyroscope is assumed to be known in principle; therefore, it is only illustrated as block 100 in figure 1. The measurement signal which is supplied by the detector 10 of the FOG 100 and contains the rate-of-rotation information

is demodulated by an FOG demodulator 13 and, since a fiber-optic gyroscope with a closed control loop is involved, is applied to the input of an FOG main controller 14, which, inter alia, on the output side, supplies a preferably non-binary U_π or resetting signal to a digital phase modulator 24, which is formed in a multifunctional integrated optical chip, i.e. an MIOC 11, and, in mirror-symmetrical embodiment, in a manner known in principle, influences the light beams on two light guiding paths L1, L2, which light beams have been produced after a beam splitting 23 and pass through a measuring coil (not shown) in opposite directions (cf. figure 2). In addition to the FOG demodulator 13 and the FOG main controller 14, an additional modulation device 15 is present, the periodic signal φE of which is on the one hand superposed on the modulation signal from the FOG main controller and then controls, via a gating filter 20, a voltage-controllable oscillator VCO 12 that determines the operating clock of the FOG gyroscope system. According to the invention, the additional modulation signal φE passes to an analog section which is formed in the MIOC 11 and - as shown in figure 2 - is realized by an additional electrode pair 25 that is independent of the digital phase modulator. The additional modulation signal φE having a small amplitude, which signal is periodic at the sampling clock rate, is thus passed to the additional electrode, or the electrode pair 25 in the example illustrated in figure 2, and typically - but in no way restrictively - produces a maximum phase shift of $\pi/32$. This phase shift is sufficient to generate, after demodulation, a signal which controls the VCO 12 via the gating filter 20 in such a way that the desired operating frequency of the FOG system is complied with exactly. In a departure from the solution described in German patent application 101 30 159.6, not published before the priority date, the periodic additional modulation signal φE, for determining the gyroscope frequency, is

not added to the digital MIOC modulation signal, but rather is passed directly to the additional analog electrode or the electrode pair 25, that is to say to the analog section 22 of the MIOC 11.

The particular advantage of the invention is that the additional modulation signal φE does not have to be digitally converted, and an addition of modulation signal and additional modulation is obviated.